INHOMOGENEOUS BROADSIDE-COUPLED STRIPLINES

Adaildo Gomes d'Assunção
Dept. of Electrical Engineering
Federal University of
Rio Grande do Norte (UFRN)
59.000 Natal, R.N., Brazil

Attilio José Giarola
Dept. of Electrical Engineering
State University of Campinas
(UNICAMP)
13.100 Campinas, S.P., Brazil

David Anthony Rogers
Dept. of Electrical
and Electronics Engineering
North Dakota State University
Fargo, N.D., 58102 USA

ABSTRACT

The integral-equation method was used in the analysis of inhomogeneous broadside-coupled striplines. The method is general and may also account for dielectric anisotropy. Curves to characterize suspended broadside-coupled microstrip lines with isotropic and anisotropic substrates are shown as examples.

Introduction

For the design of filters and directional couplers the use of parallel-coupled striplines in homogeneous media has been a common choice. There is now a growing interest in using inhomogeneous broadside-coupled striplines for these and other applications. The need for the characterization of these structures is thus evident.

Recently, Bahl and Bhartia[1] used a variational method in the Fourier transform domain to analyze inhomogeneous broadside-coupled striplines. These structures had been previously examined by Allen and Estes[2] using the variational method in the space domain. Dalley[3] and Allen[4] have shown that inhomogeneous structures may be used advantageously for the development of filters and couplers as compared to those using homogeneous structures.

In this paper an analysis of inhomogeneous structures (Fig. 1) is developed using the integral-equation method[5]. The main advantage of this technique when compared with others is that the results are easily obtained. In addition it can account directly for the dielectric anisotropy. This results from the fact that the integral form of Green's functions for the even and odd modes of the structure of Fig. 1 may be obtained directly using a highly accurate and well known algorithm[6]. The method of moments[7] is then used for the evaluation of the capacitances and other characteristics of the even and odd modes.

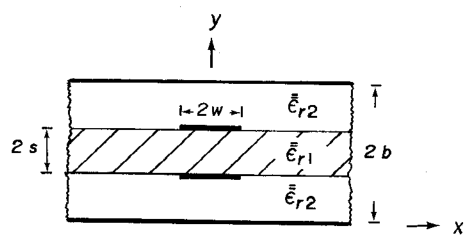

FIGURE 1: CROSS SECTION OF INHOMOGENEOUS BROADSIDE COUPLED-STRIPLINES.

The effect of the dielectric anisotropy on the characteristics of single and parallel-coupled microstrip lines has recently been reported[8,9]. This effect on broadside-coupled striplines is also reported in this paper.

Theoretical Analysis

The present analysis is restricted to TEM waves. The thickness of the conducting strips of Fig. 1 is considered very small and is neglected. Only uniaxial anisotropic substrates with their optical axis along the y-direction are considered here. Thus, the relative-permittivity tensor is diagonal.

The Green's functions of the even and odd modes were obtained separately using the elementary-strip model[6]. The method of moments was used to calculate the corresponding capacitances[7]. The characteristic impedance, Z_{0i}, the phase velocity, v_{pi}, and the effective dielectric constant, $\varepsilon_{eff\ i}$, for the mode i (even mode when i=e and odd mode when i=o) of broadside-coupled striplines (see Fig. 1) are obtained from

$$Z_{0i} = 1/c\ \sqrt{C_i C_i^v} \tag{1}$$

$$v_{pi} = c/\ \sqrt{\varepsilon_{eff\ i}} \tag{2}$$

$$\varepsilon_{eff\ i} = C_i / C_i^v \tag{3}$$

where C_i and C_i^v are the capacitances per unit length of stripline with dielectrics and with free space, respectively, and c is the velocity of light.

The Green's functions for the even and odd modes, $\Phi_{e,o}(x,b-s)$, were obtained using the elementary-strip model. Laplace's equation was solved in the regions filled with the dielectrics 1 and 2 which were assumed anisotropic (general case).

The plane y=b was considered a magnetic wall for the even mode and an electric wall for the odd mode. The result is:

$$\Phi_{e,o}(x,b-s) = \frac{1}{2\pi\varepsilon_0} \int_{-\infty}^{\infty} \frac{A(k)\cos kx\ (dk/k)}{B(k) + C(k)} \tag{4}$$

$$A(k) = [\sin\ (ka/2)]\ /(ka/2)$$

$$B(k) = n_{x1}\ n_{y1}\ [\mathrm{th}(ksn_{x1}/n_{y1})]^{-n}$$

$$C(k) = n_{x2}\ n_{y2}\ \coth(k\nu sn_{x2}/n_{y2})$$

where ε_0 is the permittivity of free space, $\nu=(b/s)-1$, and n=-1 (for the even mode) or +1 (for the odd mode); n_{x1}, n_{y1}, n_{x2}, and n_{y2} are the square roots of the xx- and yy- components of the dielectric-constant tensors of the dielectrics 1 and 2, respectively; a is the width of the elementary strip. For the line-of-charge model, a → 0. The algorithm developed by Bryant and Weiss[6] for the analysis of single microstrip lines was used to obtain the integrals represented by (4).

0149-645X/81/0000-0218$00.75

Results

Numerical results were obtained for broadside-suspended-microstrip lines with pyrolytic boron nitride ($\varepsilon_x=\varepsilon_z=5.12$; $\varepsilon_y=3.4$) and with fused quartz ($\varepsilon_r=3.78$) substrates. In Fig. 1 medium 2 is free space and the medium 1 is an isotropic or anisotropic substrate.

The characteristics of the even and odd modes were considered for $0.1 \leqslant W/b \leqslant 2.0$ and for s/b=0.05,0.1, 0.2 and 0.4. The resulting curves for the characteristic impedances, the effective dielectric constants, and the ratio between the phase velocities of the even and odd modes are shown in Figs. 2, 3 and 4, respectively. The results for the isotropic substrate agree with those presented by Bahl and Bhartia[1].

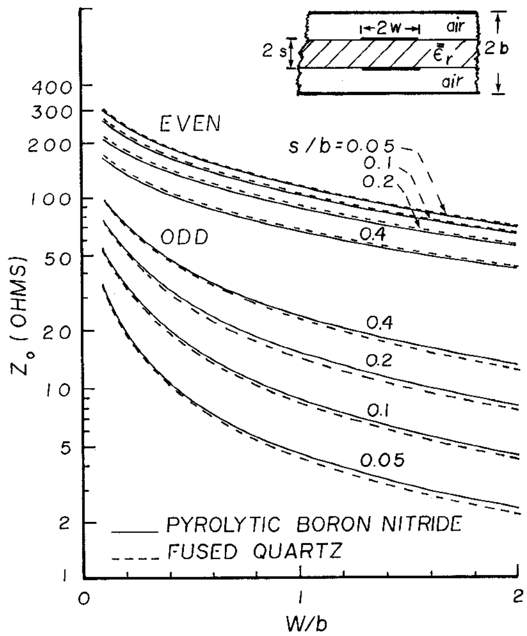

FIGURE 2: EVEN- AND ODD-MODE IMPEDANCES VERSUS W/b FOR BROADSIDE SUSPENDED MICROSTRIP LINES, WITH ISOTROPIC AND ANISOTROPIC SUBSTRATES, FOR VARIOUS VALUES OF s/b.

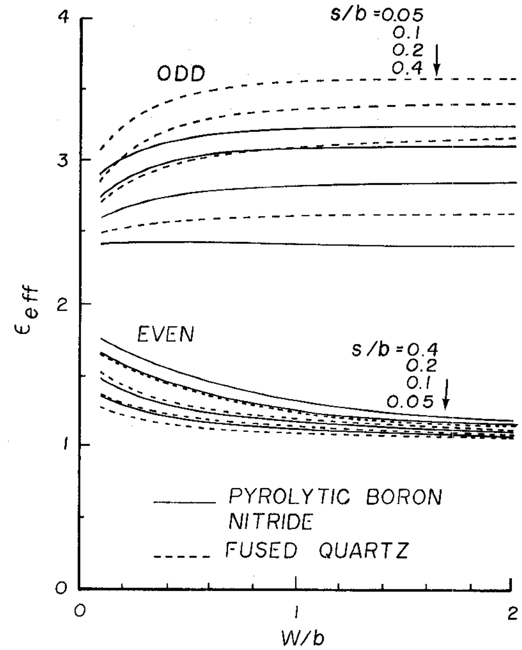

FIGURE 3: EVEN- AND ODD-MODE EFFECTIVE DIELECTRIC CONSTANTS VERSUS W/b FOR VARIOUS VALUES OF s/b AND SUBSTRATES.

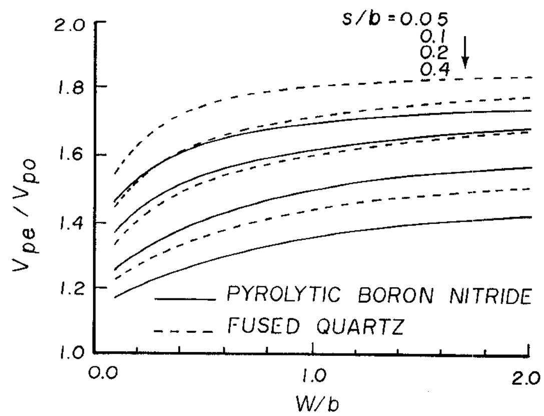

FIGURE 4: RATIO OF EVEN- AND ODD-MODE VELOCITIES VERSUS W/b FOR VARIOUS VALUES OF s/b USING ISOTROPIC AND ANISOTROPIC SUBSTRATES.

Conclusions

The integral-equation method was used for the calculation of the characteristics of inhomogeneous-broadside-coupled striplines with anisotropic or isotropic substrates. The method is efficient and accurate, even for the particular case of isotropic dielectrics.

Acknowledgements

This work was supported by Telecomunicações Brasileiras S.A. (TELEBRÁS), by the Coordenação de Pessoal de Nível Superior (CAPES) and by the Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq), Brazil.

References

1. I.J.Bahl and P.Bhartia, "Characteristics of inhomogeneous broadside-coupled striplines", IEEE Trans. Microwave Theory Tech., Vol. MTT-28, pp. 529-535, June 1980.

2. J.L.Allen and M.F.Estes, "Broadside-coupled strips in a layered dielectric medium", IEEE-Trans. Microwave Theory Tech., Vol. MTT-20, pp. 662-669; Oct. 1972. Also correction, IEEE-Trans. Microwave Theory Tech. Vol. MTT-23, p. 779, Sept. 1975.

3. J.Dalley, "A stripline directional coupler utilizing a non-homogeneous dielectric medium", IEEE Trans. Microwave Theory Tech. Vol. MTT-17, pp. 706-712, Sept. 1969.

4. J.L.Allen, "Inhomogeneous coupled-line filters with large mode-velocity ratios", IEEE Trans. Microwave Theory Tech., Vol. MTT-22, pp. 1182-1186, Dec. 1974.

5. T.G.Bryant and J.A.Weiss, "Parameters of microstrip transmission lines and of coupled pairs of microstrip lines", IEEE Trans. Microwave Theory Tech., Vol. MTT-16, pp. 1021-1027, Dec. 1968.

6. J.A.Weiss and T.G.Bryant, "Dielectric Green's function for parameters of microstrip", Electron. Lett., Vol. 6, No. 15, pp. 462-463, July 1970.

7. T.G.Bryant and J.A.Weiss, "MSTRIP (parameters of microstrip); Computer program description", IEEE Trans. Microwave Theory Tech., Vol. MTT-19, pp. 418-419, 1971.

8. N.G.Alexopoulos and C.M.Krowne, "Characteristics of single and coupled microstrips on anisotropic substrates", IEEE Trans. Microwave Theory Tech., Vol. MTT-26, pp. 387-393, June 1978.

9. M.Horno, "Calculation of quasi-static characteristics of microstrip on anisotropic substrate using mapping method", in Proc. 1980 IEEE - MTT-S International Microwave Symposium (Washington D.C.), May 1980.